Experiment with Pink Salmon: Barren Streams, Size Selection in Predation and in Trolling

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March 1984

Canadian Technical Report of Fisheries and Aquatic Sciences No. 1258

Canadian Technical Report of Fisheries and Aquatic Sciences

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Cat.No.Fs97-6/1258 ISSN 0706-6457

Correct citation for this publication:

Barber, F.G. 1984. Experiment with pink salmon: barren streams, size selection in predation and in trolling. Can. Tech. Rep. Fish. Aquat. Sci. 1258: iv + 21 p.

ABSTRACT

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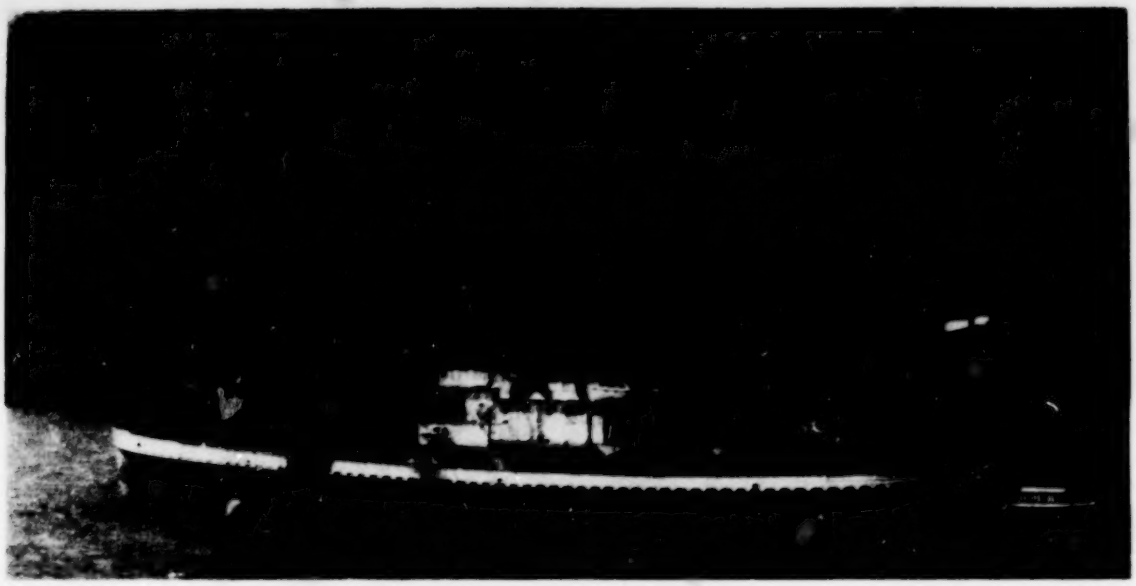
I suggest a transplant to test the speculation that because of predation streams on the ocean coast south of Juan de Fuca are without significant numbers of pink salmon; choice of donor stock could further understanding of the mechanism of predation. Complication could include the uncertain impacts of unrestricted trolling and of hatchery coho; an experimental shutdown of trolling for pink salmon is described.

RÉSUMÉ

Barber, F.G. 1984. Experiment with pink salmon: barren streams, size selection in predation and in trolling. Can. Tech. Rep. Fish. Aquat. Sci. 1258: iv + 21 p.

On suggère une transplantation afin de tester l'hypothèse selon laquelle les cours d'eau de la côte océanique au sud de Juan de Fuca contiennent peu de saumons roses à cause de la prédation. Le choix du stock parental pourrait avancer la compréhension du mécanisme de la prédation. Les complications pourraient comprendre les répercussions incertaines de la pêche à la traîne non restreinte et de la présence de saumons cohos d'élevage; on décrit une fermeture expérimentale de la pêche du saumon rose à la traîne.



HMCS Cedarwood on oceanographic survey. a) Retrieving her mooring in Bute Inlet in the summer of 1953 after the occupation with Cancolim (Barber et al. 1975, p. 2) of anchor stations in study of internal waves (Pickard 1961; photo by P. Bachelor). b) Looking forward from the starboard bridge during retrieval of a deep mooring in Queen Charlotte Sound in 1955. The centreline capstan (only partly visible) was particularly useful in the work.

INTRODUCTION

Here I attempt to deal with several seemingly disparate elements that exist in our understanding of the distribution of abundance and size of pink salmon - barren streams, size selection in predation, an influence of trolling and an influence of hatcheries - within a scheme that includes both experiment and statistics. The statistics are those of the International Pacific Salmon Fisheries Commission (hereafter IPSFC) and are about salmon (pink and sockeye) of the Fraser River. The existence of the statistics in part determined the site of the experiment; however, the experiment follows an earlier proposal for pink salmon in areas of extreme disparity and barren streams (e.g. Barber 1980a). This further suggestion for application of field experiment to a longstanding and interesting problem in the pattern of salmon distribution follows upon growing experience with other animal communities, which experience points to predation as an important determinant of populations and to the likelihood that manipulation of populations as in experiment is necessary to understanding (e.g. Lewin 1983a,b). For pink salmon both Neave (1953) and Ricker (1962; personal communication) believed predation, perhaps including cannibalism, could constitute such pressure on a population that it would remain at a very low level of abundance; Connell and Sousa (1983, p. 798) suggested that if true it would "provide strong evidence" for the view that a number of stable states are possible for apparently similar stocks. The correlation described below suggests that stability of a population may depend on a particular response, e.g. on the route of seaward migration, of a portion of the population.

The route of seaward migration of pink fry from the Fraser-Puget area appears influenced by coho predation; I (1983) speculated that:

> ...the recent increase in abundance of smolt from hatcheries has led to a significant increase in this predation, particularly in Puget Sound and Juan de Fuca Strait. Predation has reduced the proportion of fry moving seaward through Juan de Fuca and, as returning adult sockeye are coupled to the seaward migration of fry, a greater proportion has returned via Johnstone Strait.

That adult sockeye are so "coupled" is part of my speculative scheme and as shown later the "proportion" is significantly correlated ($r = 0.84$) with a measure of the abundance of fry. I visualize the coupling is the result of a physical (tidal) exchange process that effectively distributes over the coastal route the metabolic products of young, in this case of young pink salmon. Essentially I extend the exchange process believed important to the Masset system (Barber et al. 1975), which may couple returning adult and seagoing fry and so through cannibalism cause extreme disparity (Barber 1979), to the coastal waterway utilized by the young. Here both pink and sockeye adult of the Fraser are coupled to young pink (from other statistical areas) to cause through size-selective predation a strong inverse relation (to $r = -0.96$) between adult abundance in the odd year and mean whole weight the next (Barber 1980b). Predation, including cannibalism, has been observed but the evidence that either is significant or size selective remains circumstantial; some testing is necessary. Whether the results of such tests will prove separable from other influences, including those of the fishery, seems problematic, but might be separable if conducted with tests for specific influences of the fishery. But the fishery for Pacific salmon is not generally perceived "a potential variable to be manipulated" (Larkin 1979, p. 105), probably because the manipulation would require additional, perhaps complicating, regulation. However, if we are to understand the general decline in size in most Northern American pink salmon I suggest (see later) a particular manipulation, i.e. an experimental shutdown of trolling, may be necessary.

EXPERIMENT

> ...introducing salmon to barren waters
> presents the best kind of challenge...
> (Withler 1982, p. 1).

Except for "sparse or infrequent occurrences" (Neave 1952, p. 60) North American streams on the open coast south of Juan de Fuca Strait are barren of naturally spawning pink salmon (Cobb 1914; Takagi et al. 1981, p. 2), although within the normal range both barren streams (e.g. ocean coast of the Queen Charlotte Islands and Vancouver Island) and extreme disparity

(e.g. Masset Inlet and the Fraser River - Puget Sound system) do occur (Ellis and Noble 1959). In test of speculation (Barber 1979) that barren streams are the result of predation on juvenile pink by salmon smolt and adult (mainly coho, but comprising also some adult pink salmon) I proposed a field experiment for a site on an open coast, i.e. Otard Bay (Barber 1980a). Here I outline another, similar experiment on a barren stream south of Juan de Fuca, and later suggest a modification of the experiment in test of the likelihood that predation on young pink can be size selective, in particular that a predator may select for large size. The experimental objective would be to ransplant (and rear and imprint) a population of pink fry (of the odd brood year) to a stream south of Juan de Fuca for release at a number of locations close inshore between the stream and the Strait of Georgia, and to provide means (fry marked and tagged) by which the number of adult returns from each release might be compared (Note 1). (As the southern strait is an area of extreme disparity the donor stock must be of the on-year, and the on-year there is odd). I conjecture that the returns would indicate a gradient in fry survival from no survival in the vicinity of the chosen barren stream to relatively high survival for those fry released in the strait (Note 2).

But young moving oceanward from the Fraser - Puget system may pass through the Strait of Juan de Fuca to the coastal area where this predation is visualized as occurring. Why then is this system not barren? I conjecture that it would be were it not for the inner passages (e.g. Johnstone Strait) which allow some Fraser - Puget juveniles in their seaward movement to avoid significant interaction with smolt and adult. Present understanding is that by the autumn of each year most juvenile pink salmon from the Fraser - Puget system attain the ocean, either by way of Juan de Fuca or by the inner passages, but it is not known what determines the seaward route. I speculated that adult Fraser sockeye utilize the residual scent of natural products of such seaward moving fry (pink and chum) to determine their return route, i.e. whether outside or inside Vancouver Island - the percent return via Johnstone Strait has been above average in recent years (Anon. 1982a) - and that an increasing predation on fry, due to increased release of coho, was influencing route selection (Barber 1983). I suggested that the resulting increased mortality had become depensatory relative to fry that were genetically disposed to move seaward via the Strait of Juan de Fuca. I suggest

now that this mortality is naturally depensatory, i.e. was depensatory before the advent of the fishery and of significant production from enhancement facilities, and that the Fraser - Puget pink population is maintained by the return of those young that move into the ocean via Johnstone Strait.

This notion, i.e. that the southern population of pink salmon is maintained by those fry that move seaward via the inner passages, appears novel and while some support for it might occur through the experiment, I am unable to suggest a direct test. I believe that the notion follows logically from my scheme concerning selection of return route by adult Fraser sockeye, but of this also I was not able to suggest a direct test. Much of the evidence, indeed much of our understanding of the distribution and abundance of salmon in the Fraser - Puget area derives from the work of the IPSFC; estimates of the portion of adult Fraser sockeye returning via Johnstone Strait have been made from about 1953, while other estimates include the number of pink fry in the outmigration and the number of on-year adults intending to return (thus providing the marine survival each brood year), but these are not available prior to 1959 apparently (Note 3). My (1983) speculation foresaw that returning adult sockeye are coupled to seaward moving fry, mainly pink and chum, but the only fry estimates available are for pink fry. Of course the number of pink fry leaving the Fraser each even year is very much larger than the total of other fry moving seaward that year, so that the neglect of these not-estimated fry does not detract from the correlation ($r = 0.84$) between the proportion of sockeye estimated to have returned via Johnstone Strait each even year and the number of adult pink salmon estimated to have intended to return to the Fraser the next year (Note 4). Thus the estimates support the notion of a coupling between fry and adult (here pink fry and sockeye adult). However, that the Fraser population is maintained by those fry that move seaward through Johnstone Strait remains speculation, as does the notion that predation may mediate the coupling, through differential removal of particular fry. But consider that predation does mediate the coupling, and that predation in the Juan de Fuca coastal route is such as to diminish marine survival for the group of pink fry that moves into the ocean via that route (as compared to the group that utilizes the Johnstone Strait coastal route). As marine survival while in the ocean, as distinct from the coast, is likely the same on average for each group, so the relative size or number of each group that eventually

leaves the ocean (as adult) is determined by the early mortality in the coast. In my scheme it is this relative number which is significant each even year to the path taken by returning Fraser sockeye and should be reflected in the diversion; in particular, the percent sockeye diversion through one or the other strait should have direct correspondence with the fraction of returning pink adults that earlier had achieved the ocean via the particular route. But this fraction is not known (Note 5).

So I suggest that the influence of a differential coastal mortality is complete by the time the adult sockeye "lock" onto the trail left by the seaward moving juvenile pink salmon. A frustration is that the number of fry through either strait is also not known (only the total is estimated apparently), so that the dependence of marine survival on the route cannot be estimated (Note 6). If, as I suggest, barren streams result from increased predation, such estimates of marine survival could associate a mortality each year with the route, which on average for Juan de Fuca for example, could be a measure of depensatory mortality there (Note 7). In my scheme this measure is larger than in the natural (prefishery) system because of the recent influence on fry abundance of hatchery coho smolt. But another recent influence is the increased intensity and success of trolling. If, as believed, trolling selects for large fish then the recent decline in size of pink salmon may be attributed to trolling (Ricker et al. 1978; Note 8). But size is also inversely related to marine survival (Note 9) and if movement to the ocean through Johnstone Strait - as a consequence of hatchery releases - means improved survival, then some of the reduction in size may be attributed to hatcheries. We can understand the way in which trolling through selection could lead to a reduction in size - which may be open to trial (see below) - but how would mean whole weight become inversely related to marine survival? I suppose the most obvious response combines both influences: on one hand the seined on-year fish of area 20 have been heavily selected against for size by trolling before reaching area 20 (Note 9 again), while on the other hand the improved marine survival associated with passage seaward via Johnstone Strait (as I speculate) could reflect density-dependent processes (Note 10).

PROPOSAL

Limitations to trolling have been suggested (e.g. Vanderhorst 1979) and some are in place (Austin 1983); nevertheless, as it is now prosecuted trolling may be very effective (McNair 1983). That "further gear and vessel efficiency regulations would be counterproductive and of limited benefit to the resource" (Cruickshank et al. 1982, p. 3) then appears debatable, particularly as present understanding is that selection by the fishery has led to decreased age and size in some species of Pacific salmon (e.g. Ricker 1981) and as trolling without shutdowns may be the cause of the recent decline in size of pink salmon (Barber 1980b). As the decline will not likely prove a benefit to the pink salmon resource, why not shutdowns in trolling? Here I propose an experimental manipulation of the troll fishery for pink salmon to determine whether trolling is responsible for the recent decline in size of pink salmon; the fishery to be manipulated is that portion of the troll fishery targetted on those pink salmon returning to coastal streams in the odd year (Note 11). I assume the decline is reversible and that the North American odd-year fishery can be appropriately manipulated. The proposal derives directly from the detailed consideration of the statistics by Ricker et al. (1978) who saw as one of several options the "curtailment of trolling".

Much trolling is relatively unrestricted in time, at least on a weekly basis, between the dates of initial opening and final closing each year, whereas net fishing is quite restricted (Austin 1983). So although the gillnet may be selective (Hamley 1975) the frequent and lengthy shutdowns permit, in the absence of trolling, an adequate size representation in the escapement (Todd and Larkin 1971). Trolling can also be selective and pursued without shutdowns may remove larger fish, and so bias the escapement toward smaller fish. My proposal then is to arrange for shutdowns of trolling for pink salmon somewhat as exist for the net fishery, i.e. during the season each week on certain days trollers would not target (lure, speed, depth) on pink salmon.

COMMENT

> Cannibalism is believed central to extreme disparity, but whether size selection is of significance to the mechanism that produces extreme disparity is not known. (Barber 1980a, p. 18).

Present evidence is that existing odd and even year stocks of pink salmon, each from different areas, interact to produce an inverse relationship between eventual mean whole weight of adult and abundance; I suggested the mechanism included predation by returning adult on seagoing fry (Barber 1980b). So just as it seems necessary to demonstrate that trolling as presently conducted influences size, a demonstration that predation including cannibalism can influence size seems equally necessary. Consider for example the suggestion that Fraser pink salmon are largest because (as they are at the southern edge of the normal range in an area of extreme disparity) they undergo as fry relatively less size-selective cannibalism by returning adult (Barber 1980b, p. 5). And consider again the experiment for the barren stream south of Juan de Fuca and suppose that the transplanted young are from an odd-year population whose adult mean whole weight is relatively small compared to Fraser fish, e.g. they are from northern B.C. or Alaska (see Ricker et al. 1973). I conjecture that the mean whole weight of the adults in the escapement would be significantly above that of cohort returning to the northern natal (donor) stream.

ACKNOWLEDGEMENT

I wish to express my appreciation to Margaret K. Johnstone for preparation of the material for publication and the final typescript.

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NOTES

1) Extensive releases of salmon occur from facilities in the State of Washington, but not of course of pink salmon of any year to the open water south of Juan de Fuca (Castoldi and Rasch 1982; Castoldi 1983). I visualize the application in experiment of one such facility at about Grays Harbor (e.g. Hino and Eames 1982) with transport of young being achieved with a sea-going pen (Barber 1980a, p. 18). Ten equally-spaced releases might occur; one from the facility, three to Cape Flattery, three to Rosario Strait, and three to northern Strait of Georgia with the last release about Savary Island.

2) Presumably those young released in the Strait of Georgia would have a marine survival similar to that of Fraser young of that year; in recent years this has varied between 0.8 and 5.4% (see for example Table 1).

Table 1. By year of return the estimated number of pink salmon adult that intended to return to the Fraser River (catch + escapement) and the associated marine survival (from IPSFC annual reports), and for the previous year the proportion of adult sockeye that returned via Johnstone Strait (Wickett undated; Anon. 1982b, p. 11; J. F. Roos, personal communication). Column 5 is the product of the number of pink salmon intending to return (i.e. column 2) and the percent sockeye diversion the previous year (i.e. column 4) and provides in regression an illustrative but fraudulent correlation (for which see Note 5).

(1) Year	(2) Number ($X10^6$)	(3) Marine Survival (%)	(4) via JS (%)	(5) Number ($X10^6$)
1959	6.459	-	35.0	2.30
1	1.890	-	18.6	0.35
3	5.326	3.7	11.9	0.63
5	2.271	0.8	10.0	0.23
7	12.850	4.7	24.5	3.15
1969	3.849	1.6	17.6	0.68
1	9.707	5.0	23.9	2.32
3	6.753	2.8	34.0	2.30
5	4.867	1.7	21.6	1.05
7	8.173	2.9	20.8	1.70
1979	14.100	3.0	57.0	8.04
1	18.400	5.4	70.0	12.88
1983	-	-	25.0	-

3) The diversion of returning adult pink salmon is also now estimated (Anon. 1982b, p. 19).

4) I assume that the derivation of each estimate is independent of the estimate of the number of adult pink salmon intending to return. A difficulty, however, is that there are but 12 pair of numbers (Table 1), and in addition, they are not normally distributed; two pair, although aligned with the others, lie away from them and may constitute unusual leverage in the regression (Fig. 1).

5) If the percent diversion of adult sockeye each even year responds directly to the proportion of fry that attain the ocean via a particular route, and if ocean mortality is likely the same for all cohort pink fry, then the percent diversion of sockeye may be applied to the number of intending-to-return pink adult to estimate the number of intending-to-return adult that earlier as fry had attained the ocean via Johnstone Strait (Table 1, column 5); the correlation coefficient ($r = 0.95$) thus contrived indicates high significance indeed. Of course, the data sets are not independent, but are related here in illustration of the scheme. In order for the hypothesis to be sustained the relative number of fry attaining the ocean through Johnstone Strait (or Juan de Fuca) needs to be ascertained independently and then shown to be significant in a regression with sockeye diversion.

6) For young, it is generally believed that mortality while in the coastal zone is greater than in the ocean; for cohort young mortality in the ocean is constant or nearly so, and independent of the coastal route taken to attain the ocean, whereas in my scheme mortality in the coastal area is dependent on the route taken to get into the ocean.

7) At any level of depensatory mortality on established stocks a barren stream (or extreme disparity) would result, but if not sufficiently intense it would escape our experience (and perhaps experiment), i.e. the steady state of a stock undergoing a perturbation like depensatory mortality may require such long time interval that it escapes observation. Attempts to transplant to barren areas (e.g. Withler 1982) suggests that for some streams the interval is short rather than long; however, it is an aspect for which there are few data.

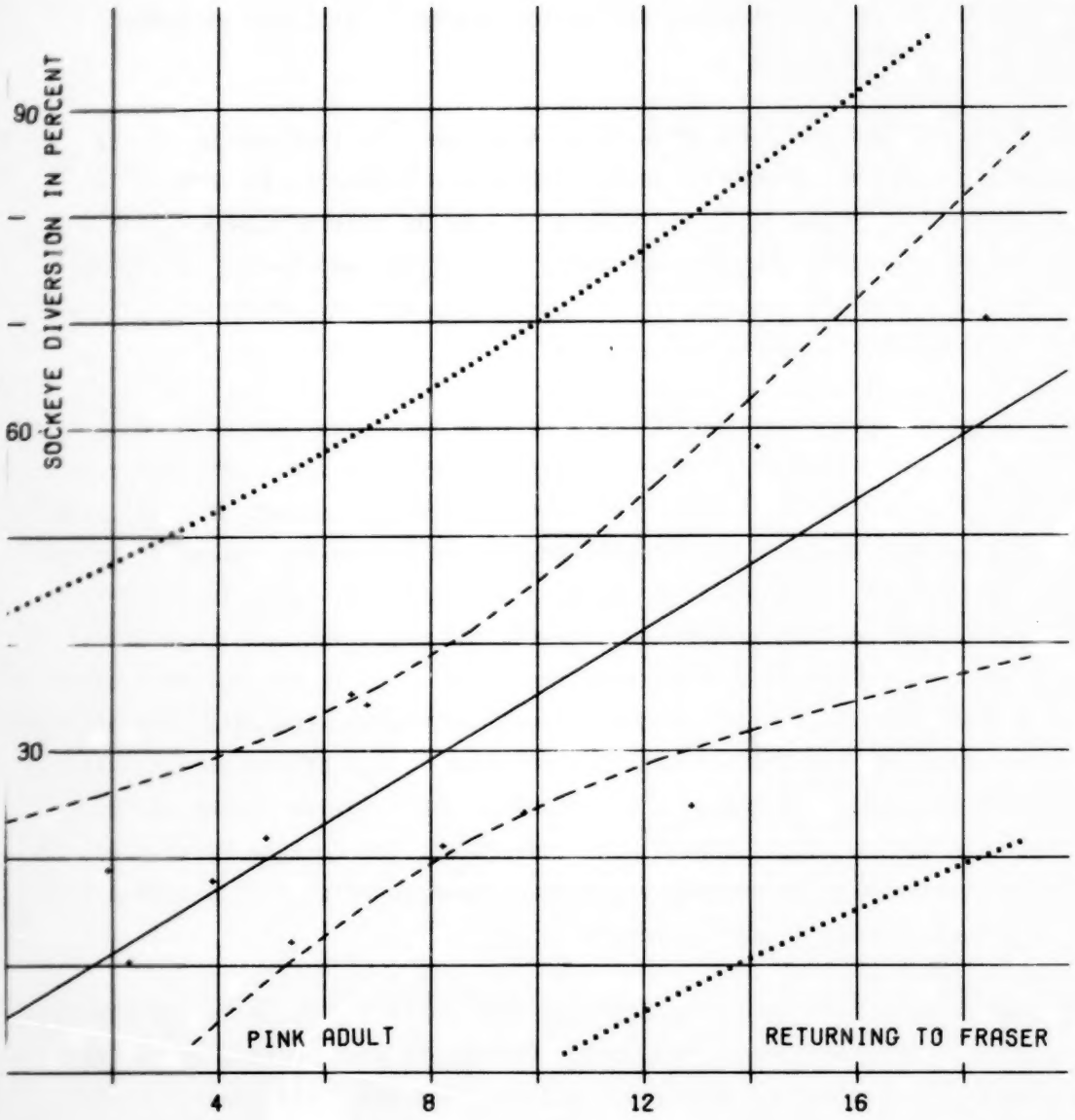

Fig. 1. Simple regression of the Johnstone Strait return (percent) in the even year on the number of pink salmon adults intending to return to the Fraser River the next year (columns 4 and 2 of Table 1). The continuous line is the regression equation, the dashed lines the limits of the equation (95% confidence level) and the dotted lines the confidence interval of the data points (95% confidence level).

8) It has not been determined whether a decline in size has occurred in Asian pink salmon of the North Pacific where trolling is not pursued, although there is evidence (Barber 1980a, p. 17) that where trolling is not a significant part of a fishery for pink salmon a decline in size has not occurred.

9) The IPSFC estimates and reports the number of pink salmon intending to return (as in Table 1), but apparently does not estimate the mean whole weight of these fish; the IPSFC does, however, report the mean whole weight of seined fish in area 20 (see below and Ricker et al. 1978, p. 35), which in the absence of trolling would presumably be representative of Fraser pink salmon intending to return (Killick and Clemens 1963).

Year of Return	Mean Weight (lb)	Year of Return	Mean Weight (lb)	Year of Return	Mean Weight (lb)	Year of Return	Mean Weight (lb)
1951	6.37	1959	5.24	1967	5.32	1975	6.00
1953	5.92	1961	6.82	1969	5.79	1977	5.80
1955	6.39	1963	5.07	1971	5.00	1979	4.80
1957	5.51	1965	6.33	1973	5.37	1981	4.90

Simple regressions indicate significant correlation ($r = -0.77$) between mean weight and abundance of returning adult (e.g. Anon. 1980, p. 24) and ($r = -0.79$) between mean weight and marine survival (of course marine survival and abundance are dependent).

10) Peterman (1978, p. 1446) considered "that there is reason to doubt the prevailing belief that marine survival of salmon is not density dependent", but more recently he came to consider the analysis provided only "little evidence for density dependence" (Peterman 1981, p. 1115). Whether for pink salmon the "prevailing belief" was ever one that rejected density dependence appears debatable; Larkin (1977, p. 175) commented that "the evidence is conflicting". Understandably, the IPSFC has kept "up front" the inverse relationship in Fraser pink salmon between on-year abundance and size (Anon. 1980, p. 24). There is however an inherent contradiction in the situation: for example the 1963 brood year produced a relatively large fry outmigration, but the return was small (marine survival only 0.8%), so that the abundance of the year

class had to change in the marine environment in time to reduce competition (presumably) and permit relatively large growth. But it seems that there exist a number of schemes by which a relation (inverse) between mean whole weight and marine survival can be contrived. For example, perhaps the increased predation by hatchery coho (mainly) in the Juan de Fuca area is size-selective, i.e. selective for small size (after Parker 1971), so that movement through Juan de Fuca would not only mean decreased marine survival but also increased mean whole weight. Or perhaps it is the larger fry on average that move seaward through Juan de Fuca and as the marine survival of this group is less, then the mean whole weight of returning adults is less; conceivably these larger fry are to a degree precocious and as a consequence "strive" to attain the ocean food resource at an earlier average age (presumably by passage through Juan de Fuca rather than Johnstone Strait the fry would achieve ocean or near-ocean condition rather sooner). In paraphrase of Healey (1967, p. 2324) about work in Burke Channel:

> Pink salmon grow at a tremendous rate during their early sea life (LeBrasseur and Parker, 1964). The food requirements necessary to maintain their high growth rate may force some fry to move seaward via Juan de Fuca.

Another scheme envisages that larger fry cannibalize smaller, such process would lead to the inverse relations between abundance and weight and between marine survival and weight. A literature review did not provide much support for the idea, for there are but six instances where a species of Oncorhynchus had in its stomach an item identified as the same species, e.g. sockeye (Synkova 1951), coho (Pritchard and Tester 1944, p. 15; Semko 1954, p. 91; Neave 1958), pink (Walker 1960) and chinook (Fresh et al. 1981, p. 17). There are rather more instances in which one species of Pacific salmon was reported to consume another species of Pacific salmon, e.g. chinook eating chum fry (Bax et al. 1980; John R. Sibert pers. com.), young masu eating pink fry (Tagmaz'yan 1971; Khorevin et al. 1982) and chum fry (Volovik and Gritsenko 1970), coho consuming young sockeye (Ricker 1937; 1941; Synkova 1951; Semko

1954; Roos 1960; Robinson and Barraclough 1978, p. 859), chinook (Fresh et al. 1981, p. 23, 27), pink fry (Pritchard 1936; 1937; Cameron 1958; Hunter 1959; Walker 1960; Parker 1971; Kaczynski et al. 1973; Robinson et al. 1982) and chum fry (Synkova 1951; Semko 1954; Hunter 1959; Sano 1966; Parker 1971; John R. Sibert pers. com.; Fresh et al. 1981; Robinson et al. 1982) and young steelhead and coho sharing a food supply that included "fry of kisutch and other species of Pacific salmon" (Neave 1958, p. 26; see also Synkova 1951). Interestingly Synkova's (1951) observation suggests that the cannibalism by young sockeye on fry occurred while the fish were still in freshwater, although it is not clear whether the predators were "residual sockeye" known to prey "upon newly emerged fry" (Foerster and Ricker 1941, p. 331; see also Ricker 1938, p. 213; Robinson and Barraclough 1978, p. 859). Ricker (1938, p. 216) remarked of kokanee that "they might consume sockeye fry and fingerlings"; later (1950, p. 13) he suggested cycle dominance in Fraser sockeye might be due to cannibalism, but not because he noticed that "fish of the dominant cycle fed on the fry of the succeeding one" (Cushing 1981, p. 161). Huntsman (1931; 1937; 1941) believed that cannibalism did occur in Atlantic salmon and so could lead to dominance. In the 1937 article he remarked (p. 25) of large parr that "...it has been shown both in nature and in experiment they will on occasion eat the salmon fry". In 1941 he said (p. 234), "There is evidence also that if very numerous, the large parr will eat the smallest salmon...". Symons and Heland (1978) in a laboratory stream observed predation by yearling Atlantic salmon on underyearling, while Bakshtansky (1965) observed Atlantic salmon smolts preying on pink and chum fry.

The possibility that adult Fraser pink salmon prey on fry, coupled with the laboratory observations of Okada and Taniguchi (1971), support the possibility "some of the larger fry could consume some of the smaller fry" (Barber 1980b, p. 20), perhaps after some achieve a particular size (Okada and Taniguchi 1971). In some fish, cannibalism can occur shortly after hatching and may be independent of size, e.g. larval walleye (Cuff 1980). Aasjord and Wallace (1980, p. 91) commented about Arctic charr in a laboratory situation that, "It is not an uncommon occurrence that a young salmonid, having become cannibalistic, will take several days to fully ingest a captured sibling of similar dimensions".

Parker and Vanstone (1966) starved young pink salmon in a small aquarium and noted cannibalism (on dead?) occurred after 10 days. Parker (1971) placed fry (pink and chum) in small aquaria with several smolt (coho) and observed a selection for smaller prey (fry) by the smolt. Remarkably, fry in an aquaria without smolt (his aquarium one) did not suffer any mortality over 18 days (some food was available). Here some fry (presumably chum) were as long as 80 mm while some (presumably pink) were as short as 30 mm; nevertheless, in this aquarium predation, including cannibalism, did not occur. And of course the considerable experience with chum and pink fry in hatcheries (e.g. Mathews and Senn 1975) and experiment (Paul et al. 1976; Urquhart and Barnard 1979a,b; Senn and Buckley 1978) is quite devoid of hint of cannibalism, although the comment that "many disappear" is suggestive (Kennedy et al. 1976, p. 5).

> During the first 40 days of marine life losses, believed to be due primarily to predation by juvenile coho..., were 77, 55, and 59%, respectively (from Parker 1968).

"Believed" may be a key word in this quotation, for Parker does not substantiate with data the relation between the percentages of loss and the marine predator (coho) although he (1971, p. 1510) did refer to "unpublished observations" in the lower reaches of the Bella Coola River, i.e. in the freshwater rather than marine environment. In the estuary the young coho apparently continue to prey on fry; he said, "Here the utilized...prey is still pink and chum fry", but again without substantive data. The notion that coho predate and that pink and chum do not, is basic to his experiment. The possibility that fry interaction would have led to losses seems not to have been considered, and if it were considered would likely have been rejected through the data on aquarium one, (wherein not one pink or chum fry was lost over 18 days). On the other hand 80 out of 500 pink fry were lost (over 17 days) for no apparent reason from aquarium four. Here many of the fry were less than 40 mm (the average size initially 43.2 mm), some as small as 30-35 mm apparently, while the larger were between 70-80 mm. If three of these larger fry had preyed on the smaller at the rate of about 2 prey

per predator day, more than the observed loss from aquarium four would have occurred. Furthermore, aquaria to which smolt were introduced, i.e. five, eight and ten, had the larger prey-per-predator-day and relatively large proportions of smaller fry, i.e. there is an association between the abundance of smaller fry and the number consumed. Parker (1971) considered it was a matter of daily ration; he said, "The number of fry making a daily ration tended to be greater when smaller fry available...". It seems now unlikely that cannibalism in aquarium four could have gone unnoticed; indeed a tally of dead fish removed each day (Parker 1971, p. 1505) could dispell the idea, but this is not clearly given.

11) A trial shutdown could be carried out for fish of either the odd or even-year (or both); I chose odd partly because of the existence of data (beginning in 1951) on the mean whole weight believed representative of Fraser River fish (Note 9 again), which would provide a basis for comparison were a trial carried out. Of course a shutdown could influence odd-year fish over much of the coast, so that evidence of a relaxation in trolling would be looked for in other statistical areas (e.g. Ricker et al. 1978). Indeed since the mean whole weight of Fraser fish may be in part under the influence of hatcheries, through the route taken to attain the ocean, the statistics from other areas may more clearly reveal a relaxation in trolling, recognising of course that fish of the Fraser may be caught in all statistical areas in the odd year (Ricker et al. 1978). Presumably then it is in statistical areas of southeast Alaska and northern British Columbia, e.g. statistical area 3 (area about the Naas River), where a response is most likely to be seen.